Case Definitions for Use in Population-Based Surveillance of Periodontitis

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Many definitions of periodontitis have been used in the literature for population-based studies, but there is no accepted standard. In early epidemiologic studies, the two major periodontal diseases, gingivitis and periodontitis, were combined and considered to be a continuum. National United States surveys were conducted in 1960 to 1962, 1971 to 1974, 1981, 1985 to 1986, 1988 to 1994, and 1999 to 2000. The case definitions and protocols used in the six national surveys reflect a continuing evolution and improvement over time. Generally, the clinical diagnosis of periodontitis is based on measures of probing depth (PD), clinical attachment level (CAL), the radiographic pattern and extent of alveolar bone loss, gingival inflammation measured as bleeding on probing, or a combination of these measures. Several other patient characteristics are considered, and several factors, such as age, can affect measurements of PD and CAL. Accuracy and reproducibility of measurements of PD and CAL are important because case definitions for periodontitis are based largely on either or both measurements, and relatively small changes in these values can result in large changes in disease prevalence. The classification currently accepted by the American Academy of Periodontology (AAP) was devised by the 1999 International Workshop for a Classification of Periodontal Diseases and Conditions. However, in 2003 the Centers for Disease Control and Prevention and the AAP appointed a working group to develop further standardized clinical case definitions for population-based studies of periodontitis. This classification defines severe periodontitis and moderate periodontitis in terms of PD and CAL to enhance case definitions and further demonstrates the importance of thresholds of PD and CAL and the number of affected sites when determining prevalence. *J Periodontol 2007;78:1387-1399.*

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Periodontitis is a chronic inflammatory disease caused by infection of the supporting tissues around the teeth. The infection begins with colonization and growth of a small group of predominantly Gram-negative anaerobic bacteria and spirochetes, notably *Porphyromonas gingivalis*, *Tannerella forsythensis*, and *Treponema denticola*.[1] These bacteria, embedded along with numerous other species in biofilms, extend apically along the surface of the tooth roots to incite formation of periodontal pockets and destruction of the alveolar bone and collagenous attachment fibers of the periodontal ligament.[2] Generally, the clinical diagnosis of periodontitis is based on measures of the presence and extent of periodontal pockets, loss of clinical attachment, the pattern and extent of alveolar bone loss, or a combination of these measures. The broader term "periodontal diseases" includes other conditions, such as gingivitis, a reversible condition that is diagnosed by the presence and extent of gingival inflammation, frequently measured as bleeding on probing (BOP).

A standard case definition of a disease is a fundamental requirement for population-based surveillance of the disease. A plethora of definitions for periodontitis has been used in the literature for population-based studies, but there is no accepted standard. In February 2003, the Division of Oral Health at the Centers for Disease Control and Prevention

(CDC), in collaboration with the American Academy of Periodontology (AAP), appointed a working group to examine the feasibility of, and to identify valid non-clinical measures for, population-based surveillance of periodontitis. A fundamental requirement for this project was the development of standardized clinical case definitions for population-based studies of periodontitis. The purposes of this article are to review and summarize the various case definitions used in population-based studies of periodontitis and to outline the standard case definitions adopted by this working group. Results of the national surveys of periodontal diseases in the United States population conducted between 1960 and 2000, along with other related clinical studies, were reviewed and summarized. The case definitions used in these surveys showed the evolution of ideas about periodontitis case definitions and provided our best estimates of the prevalence of periodontitis and the extent to which prevalence has changed over several decades.

MEASUREMENT OF INFLAMMATION, PROBING DEPTH (PD), CLINICAL ATTACHMENT LEVEL (CAL), AND ALVEOLAR BONE LOSS

Generally, the diagnosis of periodontal disease is based on the presence and extent of gingival inflammation, frequently measured as BOP,[3] PD,[4-6] CAL,[7,8] and the pattern and extent of alveolar bone loss assessed radiographically. In addition, consideration may be given to age, gingival recession, tooth mobility, medical and dental histories, previous treatment, and signs and symptoms, including pain, ulceration, and microbial deposits.[9] Because case definitions of periodontitis generally have been based on measurements of PD and CAL, and, to a lesser extent, on radiographic alveolar bone loss, this section focuses on these measurements.

PD and CAL are measured using a manual or controlled-force probe with a precision of 1 mm. PD is the distance from the gingival margin to the base of the gingival sulcus or periodontal pocket. CAL is the distance from the cemento-enamel junction (CEJ; or another definite chosen landmark) to the base of the sulcus or periodontal pocket. The accuracy and reproducibility of measurements of PD and CAL are important because case definitions for periodontitis are based largely on either or both measurements. Relatively small changes in these values can result in large changes in disease prevalence. In epidemiologic studies,[10,11] measurements of CAL and PD have been taken on all teeth, all teeth in two randomly selected quadrants (one maxillary and one mandibular), the single site with the most advanced disease in each sextant, and on selected index teeth; measurements have been made at six, four, two, and one location

per tooth. The standard deviation (SD) of repeated CAL measurements by experienced examiners using a manual probe has ranged from ~0.8 to 1.07 mm.[12,13] PD and CAL measurements are considered to be accurate to within 1 mm 90% of the time[14,15] when made by trained and experienced examiners.

In determining CAL or PD, the clinician must measure the normal distance from the CEJ to the attachment fibers or the alveolar crest around periodontally normal teeth. Determined histologically, this distance (CEJ to bone crest) has an average of 1.08 mm, with a range of 0.04 to 3.36 mm.[16] Thus, CAL must be >5.5 mm ($3.36 \pm 2\times$ SD) to ensure that periodontally normal sites are excluded from the disease category.[13]

In longitudinal clinical studies of disease progression, PD or CAL may increase by two or three times the SD.[17] Generally, increases of 2 to 3 mm have been accepted as evidence of disease progression.[18-20] CAL is accepted as the gold standard for periodontitis and is considered to be a measure of past, in contrast to current, disease activity.[9,14] Thus, CAL is considered to be a more accurate measure of history of disease and disease progression than PD. However, because it is cumbersome and time-consuming to measure, CAL is used rarely in daily clinical practice. CAL is used most commonly in clinical trials and in epidemiologic studies.

Several factors affect the accuracy of measurement of PD and CAL, and results may be an overestimate or underestimate of actual disease status. The probe tip may lodge on deposits of calculus or surface imperfections on the root surface instead of penetrating to the bottom of the pocket or sulcus. Histologic evidence showed that at sites of inflammation, the tip of the probe does not stop at the base of the sulcus or pocket but may extend to intact attachment fibers or alveolar bone crest.[21] Thus, for a given force, PD varies to some extent with inflammation; the results are considered to be more accurate for healthy sites than for diseased sites. Use of automatic probes standardizes probing force and provides automatic recording.[14,15,22] However, automated probes may underestimate PD and CAL in untreated patients.[23] Some evidence indicated that comparable results can be obtained using manual or automated probes.[14] Greater accuracy can be achieved by using the double-pass method,[14,24] but this is not practical in large surveys of prevalence and severity. Examiner variability also must be considered a factor that may affect the accuracy of measurement. Provided that trained, calibrated examiners are used, examiner variability is considered to be acceptably small.[11]

Some studies[10,11] reported that partial-mouth examinations lead to an underestimation of the prevalence and severity of periodontitis. Large studies,[25-27] such as the various national surveys conducted in

recent years, have used partial-mouth recording of two randomly selected quadrants (one maxillary and one mandibular) under the assumption that these are representative of the full-mouth status. Generally, smaller studies[28-30] have used full-mouth examinations. Measurement at the mesio-buccal and buccal sites in a random half-mouth protocol correctly identified 60% of patients with attachment loss ≥3 mm, whereas full-mouth examination of the same sites identified 74% of patients.[11] A study[31] of older adults found a high correlation coefficient (0.93) between measurements taken during half-mouth and full-mouth examinations. In the same study, in a subgroup having moderate to severe disease, disease at the buccal and mesio-buccal sites was underestimated by as much as 13%. The evidence suggests that half-mouth examinations are sufficiently accurate for studies of prevalence but are less adequate for studies of incidence, in which changes may be small.[32] Thus, all estimates of prevalence should be considered underestimates.[11]

Gingival recession presents an additional complication in making and interpreting measurements of PD and CAL and in formulating case definitions for periodontitis. Attachment loss can be reflected by periodontal pocket formation, gingival recession, or a combination of the two. In some forms of periodontal disease, attachment loss results in greater gingival recession than periodontal pocket formation.[33,34] Recession occurs more frequently and to a much greater extent in Japanese populations, for example, than in the American population.[34] Gingival recession was measured in the 1984 to 1985 national survey of periodontal disease.[5] Age-dependent gingival recession of ≤1 mm and ≥3 mm was observed in 19.7% and 2.8%, respectively, of persons aged 18 to 24 years. In the age group of 55 to 64 years, 83% and 45.6% of persons experienced ≤1 or ≥3 mm of recession, respectively. In an American population of older adults experiencing >3 mm attachment loss at mesio-buccal sites over 18 months, attachment loss caused predominantly increased PD in 58% of persons and predominant gingival recession in 42%.[28] It seems likely that some sites with recession may have had pockets at a previous stage. Nevertheless, the large proportion of cases in which recession dominates is of concern regarding the accuracy of using PD alone as a measure of disease severity and progression.

In many groups, especially in younger populations, measurements of PD and CAL correlate well, and both are accepted as measures of periodontal status. However, past middle age, attachment loss seems to continue over time;[5,17,25,26] however, as gingival recession occurs,[25] increases in PD fail to keep pace with increases in CAL, and PD and CAL no longer correlate. Using PD as the only measure of periodontal status or disease progression could be misleading because disease severity could be underestimated significantly, especially in older populations. Conversely, models of disease progression based only on CAL have had only moderate success; for example, they have only low to moderate sensitivity (i.e., determining who will get the condition).[35] These observations provide a strong argument for the use of both PD and CAL in determining case definitions.

Radiographic assessment of the extent and pattern of alveolar bone loss, as well as progression over time, also has been used to measure the severity and extent of periodontal disease. Radiographs have not been the predominant measurement in epidemiologic studies because of radiation exposure, the cumbersome nature of radiography under field conditions, and technical problems. When read by eye, radiographs must show 30% to 50% demineralization to be observable, and this results in an underestimate of the amount of bone loss.[14,36-40] With the use of subtraction techniques, changes in density as low as 5% can be detected, and there is ~80% concordance between probing measurements and radiographic methods of identifying sites that have lost attachment.[41-43] The instrumentation for digital subtraction radiography is improving dramatically in dentistry, and it may become used more widely in future clinical research.

EPIDEMIOLOGIC SURVEYS OF PERIODONTAL DISEASE

Early Studies

Application of epidemiologic methods and techniques to gingival and periodontal disease began more than a half century ago. At that time, the level of understanding of the etiology, pathogenesis, and natural history of periodontal disease was meager. The two major periodontal diseases, gingivitis and periodontitis, were combined and considered to be a continuum. Tools for measurement, disease criteria, classification, and standard case definitions did not exist.

Early epidemiologic studies focused on gingival inflammation.[44-48] The efforts of these investigators demonstrated the validity of the epidemiologic approach and stimulated the development of more sophisticated concepts and techniques for measuring the prevalence and extent of periodontal disease. Based on these observations, Russell's periodontal index (PI)[49] and the periodontal disease index (PDI)[50] were developed. Both indices were based on the concept that gingivitis was an early stage of periodontitis, and, without intervention, would progress to periodontitis. Both indices focused on the extent of soft tissue inflammation and pocket formation. Although all teeth present were evaluated in the PI, only six index

teeth were evaluated in the PDI. The PDI was the first epidemiologic method to use a partial-mouth evaluation.

The PI was a visual index of the presence of inflammation and periodontal pockets. The periodontal status of each tooth and its supporting tissue was designated as clinically normal or as having mild gingivitis, gingivitis with a periodontal pocket, advanced destructive periodontitis, or periodontitis with loss of function, and was rated accordingly on a scale of 0 to 8 (Table 1). Tooth scores were aggregated to calculate a mean score for the patient. The periodontal status for a patient was described as normal, gingivitis, beginning destructive periodontitis, established destructive periodontitis, or terminal destructive periodontitis (Table 2). This terminology and the accompanying quantification seem to be the earliest attempts to quantify the extent and severity of periodontal disease.

The PI was used extensively in epidemiologic surveys of numerous populations, including the first two national surveys in the United States. The PI was flawed, conceptually and methodologically, in that gingivitis is no longer considered to be the equivalent of early periodontitis,[51,52] and the index did not measure features specific for periodontitis (in contrast to gingivitis), such as PD, CAL, and radiographic bone loss.[53] Consequently, the index is no longer considered valid.

The Community Periodontal Index of Treatment Needs (CPITN) was developed later, under the auspices of the World Health Organization, and is known as the Community Periodontal Index.[51,54] CPITN has been used in most countries around the world. The index was not designed as a tool to assess the prevalence of periodontal disease, but rather as a way to assess treatment needs. Although the index included PD and reported the results in terms of shallow and deep pockets, it also was considered conceptually and methodologically flawed.[55] CPITN has not been used in any of the national surveys of periodontal disease conducted in the United States.

National Surveys of Periodontal Disease in the United States Population

The first National Health Examination Survey was conducted by the National Center for Health Statistics in 1960 to 1962. It focused on adults aged 18 to 79 years. Oral examinations were performed on 6,675 participants.[56] The study was repeated in 1971 to 1974 (the First National Health and Nutrition Examination Survey [NHANES I]), using essentially the same methodology, and it focused on adults aged 18 to 74 years.[57] In the second study, oral examinations were performed on 13,645 participants. Both studies have been described and compared.[57] Russell's PI was used in both studies, and examinations were conducted in a mobile examination center. Examinations lasted ~10 minutes and did not include measures of PD or CAL, and radiographs were not used. No case definitions for periodontal disease were used, except for the terminology integral to the PI, as shown in Table 2.

Only selected results of these two surveys are presented here. The proportion of participants with gingivitis decreased from ~50% in the first study to ~25% in the second, and there was a concurrent increase in the proportion of periodontally normal persons.[57] Notably, there was a concomitant decrease in plaque scores. The PI scores from the 1960 to 1962 study for all participants examined were 1.34 for men and 0.92 for women. Thus, men and women were rated as having beginning destructive periodontitis, with men in the upper range and women in the lower range. For the 1971 to 1974 study, the scores for men and women (1.28 and 0.92, respectively) had not changed significantly over the 10-year interval between the studies. An estimate of the prevalence of periodontitis for the two studies is shown in Table 3 as the proportion of participants who manifested one or more teeth with periodontal pocketing (scores ≥6 mm). For all age groups, the prevalence rates for the first and second

Table 1.

Russell's PI Scale: Scores for Individual Teeth[49]

Score	Case Definition
0	Periodontally normal
1	Mild gingivitis
2	Gingivitis
6	Gingivitis with a periodontal pocket
8	Advanced destructive periodontitis with loss of function

Table 2.

Russell's PI: Disease Scores[49]

Score Range	Case Definition
0 to 0.2	Periodontally normal
0.3 to 0.7	Gingivitis
0.7 to 1.9	Beginning destructive periodontitis
1.6 to 5.0	Established destructive periodontitis
3.8 to 8.0	Terminal destructive periodontitis

Table 3.

Prevalence of Periodontal Disease in the First and Second National Surveys[56,57]

Age (years)	Men		Women	
	1960 to 1962*	1971 to 1974†	1960 to 1962*	1971 to 1974†
18 to 79	30.1	26.6	20.0	20.4
18 to 24	10.3	7.1	9.6	5.8
55 to 64	45.6	46.9	35.5	35.8

Prevalence is reported as the percentage of the population having one or more teeth with periodontal pockets.
* NHANES (1960 to 1962).
† NHANES I (1971 to 1974).

surveys were 30.1% and 26.6%, respectively, for men and 20.0% and 20.4%, respectively, for women; they were not changed significantly over the 10-year interval. For all age groups, prevalence was higher for men than for women and increased with increasing age. When the data were analyzed by age cohort, a slight decrease was observed in the proportion of participants with pockets for groups younger than 35 years in the 1971 to 1974 study relative to the 1960 to 1962 study (data not shown). This observation provided the first evidence that the prevalence of periodontitis in United States adults may have been decreasing. Participants in the studies were classified as shown in Table 2 without any additional case definitions.

The third national survey was conducted in 1981.[5] A modification of Russell's PI was used. All teeth were scored visually for gingivitis, and PD was measured at the mesial surface of each tooth. CAL was not measured. Oral examinations were conducted in the participants' homes and included periodontal probing on the mesial surface of every fully erupted tooth, except third molars, in persons aged ≥19 years. Because a major criticism of the PI was that gingivitis and periodontitis were combined, periodontal sites were probed, and gingivitis and periodontitis were reported separately (Table 4).[5] This was the first national survey in which PD was measured and the first to present the results in terms of case definitions based on severity. Participants having gingival inflammation with PD <4 mm were classified as having gingivitis, and those with PD ≥4 mm were deemed to have periodontitis. Periodontitis was broken down into two categories based on PD, indicating moderate and advanced disease (Table 5).[5]

For this study,[5] periodontitis was defined as the presence of one or more teeth with pockets ≥4 mm. Moderate periodontitis was defined as one or more sites with PD of 4 to 6 mm. Advanced periodontitis

was defined as one or more sites with PD >6 mm. End-stage periodontitis was acknowledged, and 4% of participants were in this category. Based on these case definitions, the prevalence of periodontitis for all ages was 36.0%, that of moderate periodontitis was 28.0%, and that of advanced periodontitis was 8.0% (Table 5). These results are similar to those reported by Bailit and Manning[58] who also used the PI. The 1981 survey indicated that periodontitis was not as prevalent, extensive, or severe as observed in previous studies or as commonly believed. On the basis of radiographic bone loss, Marshall-Day et al.[48] reported that nine out of 10 persons had periodontitis by age 40; in this study,[5] only about one person in three had the disease.

The fourth national survey was conducted by the National Institute for Dental Research (NIDR) in 1985 to 1986.[25] The sample consisted of working

Table 4.

PI: Criteria for Scoring Gingivitis and PD[5]

Score	Case Definition
Gingivitis	
0	None
1	Mild gingivitis (non-circumscribing)
2	Gingivitis (circumscribing)
PD measures	
0	<4 mm
4	4 to 6 mm
6	>6 mm
8	Advanced destruction

Table 5.

Prevalence of Periodontitis by Case Definition and by Age[5]

Case Definition	Age Group (years)	%
Periodontitis	All	36.0
	19 to 44	28.8
	45 to 64	47.6
	≥65	48.2
Moderate periodontitis	All	28.0
	19 to 44	25.4
	45 to 64	31.3
	≥65	34.2
Advanced periodontitis	All	8.0
	19 to 44	3.4
	45 to 64	16.3
	≥65	14.0

adults aged 18 to 64 years who were examined at their place of employment. The data were considered to be representative of ~100 million persons. The study was conducted by trained and calibrated examiners. For the first time in a national survey, a partial-mouth examination was performed, and CAL and gingival recession were measured in addition to PD and gingivitis. The study did not use case definitions, but rather reported the data in terms of PD, CAL, and gingival recession. Two randomly selected quadrants (one maxillary and one mandibular) were evaluated, and each tooth (except third molars) was probed at the mid-buccal and mesio-buccal surfaces.

As shown in Table 6,[25] when periodontitis was defined as one or more sites with CAL ≥3 mm, the prevalence was 43.8% and 3.4 sites were affected, but when periodontitis was defined as one or more sites with CAL ≥5 mm, the prevalence decreased to 12.8% and only 0.7 sites were affected. Similarly, when periodontitis was defined as one or more sites with PD of 4 to 6 mm, the prevalence was 13.4% with 0.6 sites affected, but when periodontitis was defined as one or more sites with PD ≥7 mm, the prevalence was 0.6% and only 0.01 sites were affected. These values clearly demonstrate how relatively minor changes in PD or CAL can result in large changes in prevalence; the data emphasize the importance of threshold selection to define disease and the necessity for a high degree of accuracy in taking the measurements. The data also show that although prevalence based on CAL continues to increase with age, prevalence based on PD increases to a considerably lesser extent. For example, for the age group of 18 to 24 years, 15.7% of participants had CAL ≥3 mm, and of these, 1.9% had CAL ≥5 mm; for ages 55 to 64 years, the prevalence based

on CAL increased to 77.3% for ≥3 mm and 35% for ≥5 mm (approximately a five-fold increase). Conversely, for the age group of 18 to 24 years, 5.7% had PD of 4 to 6 mm with a negligible proportion at ≥7 mm; for ages 55 to 64 years, 18.1% had PD of 4 to 6 mm, and 1.1% had PD ≥7 mm (an increase of only about three-fold). The difference in prevalence measured by CAL and PD is likely to be due, in part, to gingival recession. The 1985 to 1986 NIDR study was the first national survey in which recession was measured. Gingival recession of ≥3 mm was observed in 45.6% of the older group but in only 2.8% of the younger group.

Prevalence reported in this study was lower than in previous studies.[5,57,58] For example, when the 1985 to 1986 NIDR study[25] was compared to the 1981 survey,[5] the NIDR study reported a lower prevalence of periodontal pockets (14% versus 36%), fewer severe pockets (0.6% versus 8%), and fewer pockets involving fewer teeth (3% versus 9% for persons with six or more teeth). Compared to the 1971 to 1974 survey (based on comparing pockets ≥4 mm to "disease with pockets"), the NIDR study prevalence was much lower for all ages.

The fifth national survey, designated NHANES III, was conducted between 1988 and 1994 using a stratified, multistage probability sample.[26] The study group consisted of 9,689 persons aged 30 to 90 years who underwent periodontal examinations. Examiners were trained and calibrated. Two randomly selected quadrants, one maxillary and one mandibular, and all fully erupted teeth (excluding third molars) in each selected quadrant were examined. Probing was performed at the mid-buccal and mesio-buccal sites of each tooth. PD, CAL, and furcation involvement were recorded, but gingival recession was not.

Table 6.

Prevalence and Extent of Attachment Loss, PD, and Gingival Recession by Age[25]

Disease Measure	Age 18 to 64 Years		Age 18 to 24 Years		Age 55 to 64 Years	
	%	Sites (N)	%	Sites (N)*	%	Sites (N)
Attachment loss (mm)						
≥1.0	99.7	34.5	—	—	—	—
≥3.0	43.8	3.4	15.7	0.7	77.3	8.2
≥5.0	12.8	0.7	1.9	<0.1	35	2.0
PD (mm)						
4 to 6	13.4	0.6	5.7	0.2	18.1	0.8
≥7	0.6	0.01	<0.1	<0.01	1.1	<0.03
Gingival recession (mm)						
≤1.0	54.4	3.9	19.7	0.7	83.7	9.5
≥3.0	17.1	0.84	2.8	<0.1	45.6	2.7

— = no data available since ages 18 to 24 years and 55 to 64 years are included in age 18 to 64 years.
* Mean number of sites.

Case definitions based on PD, CAL, and furcation grade were designated clearly in this study. Periodontitis was defined as active destruction of the periodontal supporting tissues at one or more sites, as evidenced by PD ≥3.0 mm and CAL ≥3.0 mm at the same site. Based on this definition, 35% of participants had periodontitis. Mild periodontitis was defined as one or more teeth with PD ≥3 mm or one or more posterior teeth with Class I furcation involvement. Given these definitions, 21.8% of participants were affected (Table 7).[26] Moderate periodontitis was defined as one or more teeth with PD ≥5 mm, or two or more teeth (or 30% of teeth examined) with PD ≥4 mm, or one or more teeth with Class I furcation involvement with PD ≥3 mm. In this category, 9.5% of participants were affected. Advanced periodontitis was defined as two or more teeth (or 30% of teeth examined) having PD ≥5 mm, or four or more teeth (or 60% of teeth examined) having PD ≥4 mm, or one or more posterior teeth with Class II furcation involvement. Overall, 3.1% of participants had advanced periodontitis.

For the study population, 53.1% had one or more teeth with CAL ≥3 mm, for an average of 19.6% of teeth affected per person. When the criterion was PD ≥3 mm on one or more teeth, 63.9% of persons were affected and 19.6% of teeth were affected. Furcation involvement of one or more teeth was found in 14% of participants. A comparison of the outcomes for PD and CAL between the 1985 to 1986 NIDR study[25] and the NHANES III[26] study is provided in Table 8. Disease prevalence defined as CAL ≥3 mm was similar in the two studies, whereas PD ≥4 mm was greater in the NHANES III study. The discrepancy could have resulted from differences in the study populations.

As described above for the NIDR study, the data in NHANES III also showed marked differences in prevalence in the older age groups when prevalence was based on PD alone rather than on CAL alone. As shown in Table 9 for the age groups 30 to 39, 50 to 59, and 70 to 79 years, prevalence based on CAL ≥4 mm increased with increasing age (17%, 45%, and 57%, respectively), but prevalence based on PD ≥4 mm increased only slightly or not at all (22%, 26%, and 26%, respectively).[26] The same pattern was seen for CAL and PD ≥5 mm, ≥6 mm, and ≥7 mm. This pattern is consistent with the theory that increases in PD do not keep pace with CAL because of gingival recession.

Preliminary results of the latest survey (NHANES 1999 to 2000) were reported recently.[27] This study used the same multistage probability sampling procedure and the same periodontal examination protocol as in NHANES III. The population consisted of persons aged ≥18 years. Several case definitions of periodontitis were tested (results not yet published); the one used in the data analysis was at least three sites with CAL ≥4 mm and at least two sites with PD ≥3 mm. These conditions did not have to be present at the same site or on the same tooth. The reported prevalence of periodontitis with the above case definition was 4.2% for the combined white, Hispanic, and African American populations. This compares to a prevalence of 7.3% for the NHANES III population when the same case definition was used. Data permitting a comparison of results for various CAL and PD thresholds between the present study and previous NHANES studies have not been reported. Notably, differences in prevalence among whites, African Americans, and Hispanic Americans observed in NHANES III and the NIDR study were not observed in this study. This observation is important for the CDC surveillance project because the United States population subgroups now seem to be more homogeneous with regard to the prevalence and severity of periodontitis.

Table 7.

Prevalence of Periodontitis by Case Definition[26]

Case Definition	%	N Patients (millions)
No periodontitis	65.5	67.9
Mild periodontitis	21.8	22.6
Moderate periodontitis	9.5	9.9
Advanced periodontitis	3.1	2.3

Table 8.

Prevalence of Periodontitis in Two National Surveys[25,26]

| Disease Measure | NIDR 1985 to 1986 Study | | NHANES III Study | |
	Age 35 to 44 Years	Age 55 to 69 Years	Age 40 to 49 Years	Age 60 to 69 Years
CAL ≥3 mm	48.6%	77.3%	48.5%	74.8%
PD ≥4 mm	17.2%	19.2%	21.4%	25.4%

Summary of the National United States Studies
The case definitions and protocols used in the six national surveys reflect a continuing evolution and improvement over time. However, they were sufficiently different so detailed direct comparisons are difficult. Nevertheless, it is clear that the prevalence and severity of periodontitis have decreased significantly over the last 50 to 60 years. Whether the current prevalence is as low as reported in the NHANES 1999 to

Table 9.

Differences in the Prevalence of Periodontitis by CAL, PD, and Age

	Age 30 to 39 Years		Age 50 to 59 Years		Age 70 to 79 Years		All Ages	
	CAL	PD	CAL	PD	CAL	PD	CAL	PD
≥3 mm	36	66	66	62	79	56	53	64
≥4 mm	17	22	45	26	57	26	33	23
≥5 mm	8	7	27	10	42	11	20	10
≥6 mm	4	3	16	5	26	6	12	4
≥7 mm	3	1	9	3	17	2	7	2

Data are reported as percentage of affected persons (modified from Albandar et al.[26]).

2000 study seems uncertain. The case definition used in that study was more stringent than those used in previous national surveys. Although other case definitions were tested, the results have not been published. It is notable that when the same case definition was applied to the NHANES III data set, the prevalence was 7.3%, in contrast to the 13% reported by Albandar et al.[26] Based on current knowledge, the best estimate of the prevalence of moderate to severe periodontitis in the adult American population is likely to be between 4% and 10%. All of these studies demonstrated the enormous importance of thresholds of PD and CAL and the number of affected sites required in the case definitions. Clearly, slight changes in these values can cut in half (or double or triple) the reported prevalence.

DIAGNOSES AND CASE DEFINITIONS FOR PERIODONTITIS

Many classification schemes for periodontal diseases have been proposed over the past century. The classification that is currently accepted by the AAP was devised by the 1999 International Workshop for a Classification of Periodontal Diseases and Conditions.[59] The classification consists of the disease conditions listed in Table 10. Although this classification may be useful to clinicians, it is of little value in establishing case definitions for use in the surveillance of periodontitis in the United States population. The CDC is interested in surveillance of plaque-associated periodontitis, not gingivitis. Chronic and aggressive periodontitis account for >95% of all cases of periodontitis. Cases of periodontal abscess and those that reflect systemic disease fall into the category of chronic and aggressive periodontitis. Periodontic or endodontic lesions are very rare, and necrotizing periodontitis is almost never seen except in patients with impaired immune systems. For the purposes of surveillance, there seems to be no reason for separating chronic and aggressive periodontitis.

Table 10.

Currently Accepted Classification of Periodontal Diseases[59]

Gingivitis

Chronic periodontitis

Aggressive periodontitis

Periodontitis as a manifestation of systemic diseases

Necrotizing periodontal diseases

Abscesses of the periodontium

Periodontitis associated with endodontic lesions

The diagnosis of periodontitis is based almost entirely on traditional clinical and radiographic assessments.[15,60] Features used most commonly include measurements of PD and CAL, the radiographic pattern and extent of alveolar bone loss, and a measurement of inflammation, such as BOP. Also considered are tooth mobility; medical and dental histories; and miscellaneous signs and symptoms, including pain, ulceration, and observable plaque and calculus.[14,59,61] A plethora of diagnostic terms has been used. Some of these have been based on severity, including early or mild periodontitis, moderate periodontitis, and severe or advanced periodontitis, and these have been modified by terms for extent, including "localized" or "generalized."[9] In many clinical studies,[13,62-66] investigators used their own case definitions for substantial disease, such as advanced, serious, or severe, based on varying combinations of CAL, PD, BOP, and extent of bone loss. Generally, terms have been defined empirically, and there has been no consensus about the criteria for these diagnoses.

Case definitions for periodontitis differ from diagnoses because they must be more quantitative and

specific, accurately measurable, and relatively few in number. To establish case definitions for periodontitis, one must determine the threshold values for CAL, PD, or both at a given site that constitutes unequivocal evidence of periodontitis at that site, as well as the number of such sites that must be involved to establish disease.[67] Selection of threshold values is critical. Minor changes in the threshold values for CAL, PD, and the number of affected sites used in the case definitions result in major changes in the prevalence scores.

Many case definitions have been proposed and used in epidemiologic and other clinical studies[5,8,13,25-27,56,64,68,69] (Tables 11 and 12). The most distinctive feature of these case definitions is their extreme variation and lack of uniformity. Some definitions use a combination of PD and CAL, whereas others are based on PD or CAL alone. No consensus has been reached on the threshold values for PD and CAL or on the numbers of sites or teeth that must be affected to constitute disease. The AAP has attempted to introduce some degree of specificity. Chronic periodontitis with slight to moderate loss of

periodontal support was defined as localized or generalized loss of up to one-third of the supporting periodontal tissues, including Class I furcations, with PD measuring up to 6 mm and CAL up to 4 mm.[70] Chronic periodontitis with advanced loss of periodontal support was defined as localized or generalized loss of more than one-third of the supporting periodontal tissues with furcation involvement higher than Class I, PD >6 mm, and CAL >4 mm.[71] Neither case definition considers the number of teeth affected, and neither is precise and quantitative enough to meet CDC needs.

CDC WORKING GROUP CASE DEFINITION FOR POPULATION-BASED STUDIES OF PERIODONTITIS

The case definitions for periodontitis developed by the CDC Periodontal Disease Surveillance Workgroup are shown in Table 13. Two definitions are provided for periodontitis: one for severe periodontitis and another for moderate periodontitis. The case definition for severe periodontitis is stringent to ensure that patients identified by the definition do have the disease. The

Table 11.

Case Definitions and Prevalences Used in United States National Surveys

Study	Age (years)	Case Definition	Prevalence (%)	Reference
HES 1960 to 1962	18 to 79	≥1 tooth with pocket	25	56
HES 1971 to 1974	18 to 74	≥1 tooth with pocket	25.5	
1981 National Survey	≥19	Periodontitis: ≥1 site, PD ≥4 mm Moderate: ≥1 site, PD 4 to 6 mm Severe: ≥1 site, PD ≥6 mm	36 28 8	5
NIDR 1985 to 1986	18 to 64	≥1 site with CAL ≥3 mm ≥1 site with PD 4 to 6 mm ≥1 site with CAL 5 mm ≥1 site with PD ≥7 mm	43 13.4 12.8 0.6	25
NHANES III	30 to 90	Periodontitis: ≥1 tooth with CAL ≥3 mm + PD ≥4 mm (same site) Mild: ≥1 tooth with PD ≥3 mm or ≥1 Class I furcation Moderate: ≥1 tooth with PD ≥5 mm or ≥2 teeth with PD ≥4 mm or ≥1 Class I furcation + PD 3 mm Severe: ≥2 sites with PD ≥5 mm or ≥4 sites with PD ≥4 mm or ≥1 tooth with Class II furcation ≥3 mm CAL ≥3 mm PD	35 21.8 9.5 3.2 53.1 (19.6% of teeth) 63.9 (19.6% of teeth)	26
NHANES 1999 to 2000	≥18	Periodontitis: ≥3 sites with CAL ≥4 mm + ≥2 sites with PD ≥3 mm	4.2	27

HES = National Health Examination Survey.

Table 12.

Case Definitions and Prevalence Used in Other Clinical Studies

Study	Case Name	Case Definition
Machtei et al.[13]	Established periodontitis	≥2 teeth with CAL ≥6 mm + ≥1 site with PD ≥5 mm
Moore et al.[68]	Severe generalized periodontitis	≥8 teeth with CAL ≥5 mm, PD ≥6 mm
Burmeister et al.[8]	Severe generalized periodontitis	≥8 teeth with CAL ≥5 mm (≥3 teeth not first molars)
Beck et al.[64]	Severe destructive periodontitis	≥4 sites with CAL ≥5 mm; ≥1 same sites PD ≥4 mm
Tomar and Asma[69]	Periodontitis	≥1 site with CAL ≥4 mm, PD ≥4 mm

Table 13.

Clinical Case Definitions Proposed by the CDC Working Group for Use in Population-Based Surveillance of Periodontitis*

	Clinical Definition		
Disease Category	CAL		PD
Severe periodontitis	≥2 interproximal sites with CAL ≥6 mm (not on same tooth)	and	≥1 interproximal site with PD ≥5 mm
Moderate periodontitis	≥2 interproximal sites with CAL ≥4 mm (not on same tooth)	or	≥2 interproximal sites with PD ≥5 mm (not on same tooth)
No or mild periodontitis	Neither "moderate" nor "severe" periodontitis		

* Third molars excluded.

definition probably excludes some bona fide cases of periodontitis. To address this problem, the case definitions for moderate periodontitis are intended to detect patients who have less severe periodontitis and to identify patients who may be excluded incorrectly from the severe category.

The case definition for severe periodontitis requires two or more interproximal sites with CAL ≥6 mm, not on the same tooth, and one or more interproximal sites with PD ≥5 mm. Interproximal sites, in contrast to buccal or lingual sites, are required because the disease usually begins and is most severe at interproximal sites and because this minimizes the effects of gingival recession on the accuracy of the PD measurements. At least two sites with CAL ≥6 mm, not on the same tooth, are required because it is possible to have abnormal CAL and not have periodontitis.[13] Such conditions include a subgingival restoration with an overhanging margin and the distal aspect of some mandibular second molars where a third molar has been extracted. In addition, the requirement takes into account evaluator variation and the underestimation of disease known to result from partial-mouth examinations.

Both CAL and PD measurements are required for several reasons. Although CAL is considered a more accurate measure than PD, and CAL is accepted as the gold standard for disease severity and progression, use of CAL alone could mistakenly include some periodontally healthy sites because attachment loss can accompany non-inflammatory gingival recession. A patient or a tooth with periodontitis can be treated successfully or the disease can resolve spontaneously without a return of CAL to normal. Furthermore, attachment loss can be due to non-inflammatory causes. Despite their benefits, models of disease progression based on CAL have been only moderately successful because of low to moderate sensitivity.[35]

Use of PD alone probably would result in an underestimate of prevalence, especially in older persons. PD and CAL are equivalent measures of periodontitis at younger ages. After middle age, CAL continues to advance; however, PD slows because of gingival recession, and it no longer has a high correlation with CAL. The case definition requires at least one site with PD ≥5 mm, in part to rule out patients who have been treated successfully but still have attachment loss or have attachment loss not resulting from periodontitis.

The threshold for CAL was set at ≥6 mm. The mean distance from the CEJ to the alveolar bone crest is ~1.0 mm, and the range is 0.04 to 3.36 mm.[13,16] At diseased sites, the probe tip may extend beyond the bottom of the pocket because of inflammation, and because the SD for CAL measurements is ~1 mm, a threshold value of <6 mm probably would include some healthy sites.[13] The proportion of sites with bona fide attachment loss that show gingival recession rather than pocket formation, or recession and pocket formation, is significant (Table 6).[28]

Moderate periodontitis was defined as two or more interproximal sites with CAL ≥4 mm, not on the same tooth, or two or more interproximal sites with PD ≥5 mm, not on the same tooth. As with the definition for severe periodontitis, the case definition for moderate periodontitis includes two or more affected sites and sites with CAL, abnormal PD, or both. The definitions are likely to pick up cases of severe periodontitis that are missed by the severe periodontitis case definition and moderate cases of periodontitis.

It is hoped that these definitions will serve as standard case definitions for population-based surveillance of moderate and severe periodontal disease for the future, which will bring some uniformity to case definitions of the disease across studies.

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